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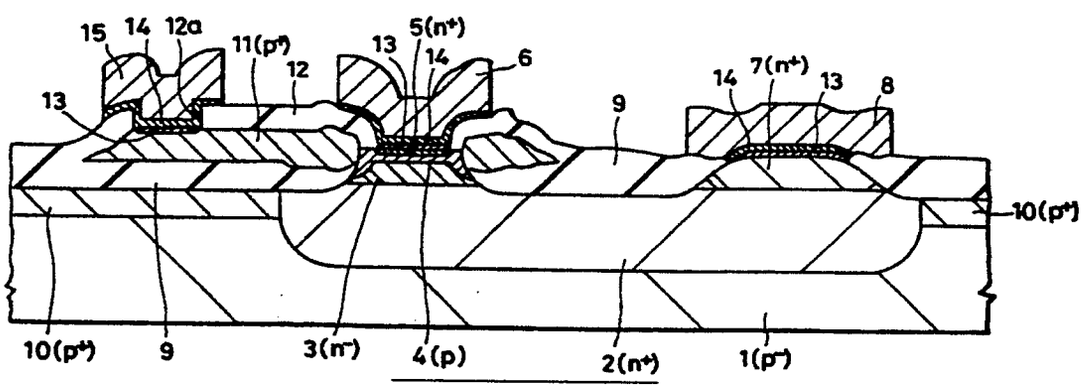
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(54) Electrodes for semiconductor devices.

(57) On a semiconductor film (11) to function as a lead-out electrode of a semiconductor element, a metal silicide film (13) and a metal nitride film (14) are successively provided, whereby alloying and inferior contact resistances attributed to heat during wiring with aluminum can be effectively suppressed, so that the reliability of a semiconductor device can be enhanced.

FIG. 1



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Semiconductor Device

BACKGROUND OF THE INVENTION

The present invention relates to a semiconductor device, and more particularly to a technique which is effective when applied to the formation of an electrode in the case of employing a semiconductor film for leading out the electrode.

In, for example, a bipolar LSI of SICOS (Side Wall Base Contact) structure, the base of a bipolar transistor is led out by a boron-doped polycrystalline Si (silicon) film, on which an Al-alloy electrode is formed (refer to, for example, the official gazette of Japanese Patent Application Laid-open No. 1556/1981).

Besides, the emitter, base and collector of a bipolar transistor are led out by multilayer films each consisting of a polycrystalline silicon film and platinum silicide (PtSi), and aluminum electrodes (wiring layers) are formed on the polycrystalline silicon films (described in, for example, IEEE JOURNAL OF SOLID-STATE CIRCUITS, VOL. SC-15, No. 4, AUGUST 1980, pp 455-458).

Hereinbelow, for the sake of convenience, the expression "electrode" shall sometimes comprehend, for example, a lead-out conductor layer which is connected near the contact hole of an aluminum wiring layer or to a base, emitter or collector or a source or drain diffused layer.

SUMMARY OF THE INVENTION

The inventors studied the electrode formation on the polycrystalline Si film and the elctrode formation on the multilayer film consisting of the polycrystalline Si film and platinum silicide. The technique studied by the inventors, which was not known, will be outlined below:

According to the results of experiments conducted by the inventors, a polycrystalline Si film doped with boron is far more difficult of the growth of crystal grains as compared with a polycrystalline Si film doped with arsenic or phosphorus, and the crystal grain growth of the former hardly takes place in the manufacturing process of an LSI. In consequence, the boron-doped polycrtstalline Si film is in an unstable state in which the film itself stores large quantities of grain boundary energy. Therefore, in a case where an electrode made of an Al-alloy film is formed directly on the boron-doped polycrystalline Si film, the problem arises that the electrode is alloyed with the polycrystalline Si film during the formation thereof, so a defective unit is manufactured.

For such a reson, in a bipolar LSI wherein a base is led out by the boron-doped polycrystalline Si film, after the polycrystalline Si film has been formed, an electrode made of an Al-alloy film is formed thereon through a platinum silicide (PtSi) film.

The inventors, however, have found out that, even in the case where the electrode made of the Al-Si-alloy film is formed on the polycrystalline Si film through the platinum silicide film as stated above, the refractoriness of the electrode is not sufficient, so the alloying between the electrode and the polycrystalline Si film is prone to occur during the formation of the Al-alloy electrode. Further, in a case where a transition metal or an alloy thereof, such as W, Mo or TiW, is used instead of the platinum silicide film, the refractoriness is still insufficient because the material itself has the property of easily reacting with Si to form a silicide.

An object of the present invention is to provide a technique capable of enhancing the refractoriness of an electrode.

The above and other objects and novel features of the present invention will become apparent from the description of this specification and the accompanying drawings.

A typical aspect of performance of the present invention is as summarized below:

A metal silicide film and a metal nitride film which is electrically conductive are successively disposed on a semiconductor film, and an electrode is disposed on the metal nitride film.

According to the above expedient, the alloying between the semiconductor film and the electrode is effectively prevented especially by the metal nitride film, so that the refractoriness of the electrode can be enhanced. Moreover, the contact resistance of the electrode can be stabilized by the metal silicide film.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a sectional view which shows a bipolar LSI or SICOS structure according to Embodiment I of the present invention; and

Fig. 2 is a sectional view which shows complementary metal-oxide semiconductor field effect transistors (CMOSFET's) according to Embodiment II of the present invention.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Now, the construction of the present invention will be described on the basis of embodiments with reference to the drawings.

[Embodiment I]

As illustrated in Fig. 1, in a bipolar LSI of SICOS structure according to Embodiment I, a semiconductor substrate 1 such as a p^--type Si substrate by way of example is provided with a buried layer 2 of n^+-type. A Si epitaxial layer 3 of, for example, n^--type is disposed on the semiconductor substrate 1. The part of the Si epitaxial layer 3 overlying one end of the buried layer 2 is etched into the shape of a mesa, on which a base region 4 of p-type is disposed. Further, an emitter region 5 of n^+-type is formed in the base region 4. An emitter electrode 6 made of, for example, an Al-Si-alloy film is disposed on the emitter region 5 through a metal silicide film 13 and a metal nitride film 14 which will be described later. A collector region of n-type is configured by the Si epitaxial layer 3 between the base region 4 and the buried layer 2. Numeral 7 denotes an electrode lead-out region of n^+-type which is connected with the buried layer 2, and a collector electrode 8 made of, for example, an Al-Si-alloy film is formed on the electrode lead-out region 7 through a metal silicide film 13 and a metal nitride film 14 to be described later.

Meanwhile, a field insulator film 9 such as an SiO_2 film by way of example is formed around the mesa-shaped part of the Si epitaxial layer 3, whereby the elements of the LSI are isolated. Under the field insulator film 9, a channel stopper region 10 of p^+-type is formed, thereby to prevent a parasitic channel from appearing. In addition, a polycrystalline Si film 11 of p^+-type which is heavily doped with boron by way of example is formed on the field insulator film 9 so as to be connected with the base region 4, whereby the base is led out. On the surface of the polycrystalline Si film 11, an insulator film 12, for example, SiO_2 film which is formed by, for example, the thermal oxidation of this polycrystalline Si film 11 is provided continuously to the field insulator film 9.

A contact hole 12a is provided in the part of the insulator film 12 corresponding to one end of the polycrystalline Si film 11. Through this contact hole 12a, the polycrystalline Si film 11 is overlaid with a metal silicide film 13 such as a platinum silicide film or palladium silicide film having a thickness of about 20 nm by way of example and a metal nitride film 14 such as a titanium nitride (TiN) film having a thickness of about 100 nm by way of example, and a base electrode 15 made of an Al-Si-alloy film by way of example is formed on the metal nitride film 14. The metal nitride film 14 is ceramics having an electric conductivity, which is very stable thermally and excellent in refractoriness and which also exhibits a low reactivity with Si. Therefore, the metal nitride film 14 can effectively prevent the occurrence of the alloying of the electrode 15 with the polycrystalline Si film 11 at the step of forming this electrode, and it can consequently enhance the refractoriness of the electrode. Accordingly, enhancement in the reliability of the electrode can be achieved. Furthermore, owing to the metal silicide film 13, the contact resistance of the electrode 15 with respect to the polycrystalline Si film 11 can be stabilized. In the case where the metal silicide (PtSi) film 13 and the metal nitride (TiN) film 14 are formed on the polycrystalline Si film 11 in the order mentioned, the contact resistance of the aluminum electrode (wiring layer) 15 remains constant for above 10 hours in spite of annealing at 475 °C.

Next, a method of manufacturing the bipolar LSI according to the embodiment I will be described.

First, as illustrated in the drawing, a buried layer 2, a Si epitaxial layer 3, a field insulator film 9, a channel stopper 10 and a boron-doped polycrystalline Si film 11 are formed, whereupon the surface of the Si epitaxial layer 3 is thermally oxidized in the state in which it is covered with an oxidation impermeable film (not shown) such as an Si_3N_4 film by way of example, thereby to form an insulator film 12 on the surface of the polycrystalline Si film 11. Subsequently, an electrode lead-out region 7 is formed within the Si epitaxial layer 3 by, for example, the selective diffusion of phosphorus, whereupon a p-type impurity and an n-type impurity are successively ion-implanted by way of example, thereby to successively form a base region 4 and an emitter region 5 within the Si epitaxial layer 3. Subsequently, the predetermined parts of the insulator film 12 are etched and removed to form contact holes 12a. Subsequently, a metal film such as a platinum film or palladium film by way of example is formed on the whole surface of the resulting structure by, for example, evaporation and is sintered by a predetermined annealing, whereupon the unreacted metal film is etched and removed with, for example, aqua regia (a mixed solution consisting of HCl and HNO_3), thereby to form metal silicide films 13 such as platinum silicide films or palladium silicide films on the parts of the polycrystalline Si film 11, the emitter region 5 and the electrode lead-out region 7 corresponding to the contact holes 12a. Subsequently, a metal nitride film 14 such as a titanium nitride film by

way of example is formed on the whole surface by, for example, sputtering, whereupon an Al-Si-alloy film, for example, is further formed on the whole surface of the metal nitride film 14. These films are successively patterned into predetermined shapes by, for example, dry etching, thereby to form electrodes 6, 8 and 15. Then, an intended bipolar LSI is finished up as shown in the drawing.

[Embodiment II]

As illustrated in Fig. 2, in complementary metal-oxide semiconductor field effect transistors (hereinbelow, abbreviated to "CMOSFET's") according to Embodiment II, a semiconductor substrate 1 such as a p^--type Si substrate by way of example is provided with an n-type well region 16. A field insulator film 9 made of, for example, an SiO_2 film is disposed on the selected area of the surface of the semiconductor substrate 1. The active region of the n-type well region 16 is overlaid with a gate insulator film 17 which is made of an SiO_2 film, a gate electrode 18 which is made of a polycrystalline Si film formed by, e. g., CVD, a p-type diffused layer 19 which is formed by the ion implantation of boron (B), a side wall 21 which is made of an SiO_2 film formed by CVD, and p^+-type source and drain diffused layers 22 which are formed by the ion implantation of boron (B), whereby a p-type MOSFET of lightly doped drain (hereinbelow, abbreviated to "LDD") structure is constructed. Meanwhile, likewise to the p-type MOSFET, the active region of the other region than the N-type well region 16 is overlaid with a gate insulator film 17 which is made of an SiO_2 film, a gate electrode 18 which is made of a polycrystalline Si film, an n^--type diffused layer 20 which is formed by the ion implantation phosphorus (P), a side wall 21 which is made of an SiO_2 film, and n^+-type source and drain diffused layers 23 which are formed by the ion implantation of arsenic (As), whereby an n-type MOSFET of LDD structure is constructed. Polycrystalline Si films of p^+-type 11A which are heavily doped with, e. g., boron (B) are disposed on the p-type source and drain diffused layers 22 of the p-type MOSFET, while polycrystalline Si films of n^+-type 11B which are heavily doped with, e.g., phosphorus (P) are disposed on the n^+-type source and drain diffused layers 23 of the n-type MOSFET, whereby the sources and drains of both the MOSET's are respectively led out. On each of the polycrystalline Si films 11A and 11B, a metal silicide film 13 which is a platinum silicide film about 20 nm thick by way of example and a metal nitride film 14 which is a titanium nitride (TiN) film about 100 nm thick by way of example are provided for the same purpose as in Embodiment I. An inter-layer insulator film 24 made of an SiO_2 film is formed on the whole surface of the resulting p^--type Si substrate 1, and it is selectively etched, whereby contact holes 12B are provided in predetermined parts. Wiring layers 15 made of Al-Si-alloy films by way of example are provided, and are respectively connected to the metal nitride films 14 through the contact holes 12B. The wiring layers 15 selectively connect the electrodes of elements. As in Embodiment I, the lead-out electrodes constructed of the polycrystalline Si films 11A, 11B, metal silicide films 13 and metal nitride films 14 are excellent in refractoriness and stabilize the contact resistances of the wiring layers 15 made of the Al-Si-alloy films. A protective film 25 which is made of a multilayer film consisting of an SOG film and a PSG film by way of example is provided on the wiring layers 15, etc.

Next, a method of manufacturing the CMOSFET's according to Embodiment II will be described.

As illustrated in the drawing, an n-type well region 165, a field insulator film 9, gate insulator films 17, gate electrodes 18, p^--type diffused layers 19, n^--type diffused layers 20, side walls 21, p^+-type diffused layers 22 and n^+-type diffused layers 23 are successively formed by well-known processess for producing MOSFET's. Thereafter, a polycrystalline silicon film for forming p-type polycrystalline silicon films 11A and n-type polycrystalline silicon films 11B is formed on the whole surface of the resulting p^--type Si substrate 1 by, e. g., CVD, and impurities such as boron (B) and phosphorus (P) are respectively diffused into the selected parts of the polycrystalline silicon film formed. After the selective diffusion of the impurities, a metal silicide film made of platinum silicide and a metal nitride film made of titanium nitride are successively stacked and formed on the whole surface of the polycrystalline silicon film by the same method as in Embodiment I. Further, the selected parts of the metal nitride film, metal silicide film and polycrystalline silicon film formed as described above are continuously etched by, for example, anisotropic dry etching, thereby to form source and drain lead-out electrodes made up of the polycrystalline silicon films 11A, 11B, metal silicide film 13 and metal nitride film 14. Thenceforth, inter-layer insulator films 24 made of SiO_2, wiring layers 15 made of an Al-Si alloy, and a protective film 25 consisting of an SOG film and a PSG film are successively formed by well-known processes, whereby intended CMOSFET's are finished up.

Although, in the above, the invention made by the inventors has been concretely described in conjunction with the embodiments, it is a matter of course that the present invention is not restricted to the foregoing embodiments, but that it can be variously modified within a scope not departing from the gist thereof.

By way of example, while the foregoing embodiments have referred to the cases of applying the present invention to the bipolar LSI and the CMOSFET's which employ the boron-doped polycrystalline Si film 11 for leading out the base, the present invention is also applicable to a case as explained below. As already stated, a polycrystalline Si film doped with phosphorus or arsenic is more liable to the growth of crystal grains than a polycrystalline Si film doped with boron. However, when the phosphorus-or arsenic-doped polycrystalline Si film has the quantity of doping set smaller than the limit of solid-solubility of the impurity in Si to the end of using the film as, for example, a resistance element, it is difficult of undergoing the growth of cyrstal grains likewise to the boron-doped polycrystalline Si film, and the sizes of the crystal grains sometimes have values which are smaller than the thickness of the polycrystalline Si film by way of example. Even in the case of forming an electrode on such a polycrystalline Si film doped with phosphorus or arsenic below the limit of solid-solubility, the present invention can be applied and can thus enhance the refractoriness of the electrode.

In addition, the present invention can be applied to bipolar LSI's not having the SICOS structure and also to various semiconductor devices other than bipolar LSI's.

Claims

1. A semiconductor device having an electrode (6, 8, 15) provided on a semiconductor film (5, 7, 11),
characterized in that a metal silicide film (13) and an electrically conductive metal nitride film (14) are successively provided on said semiconductor film (5, 7, 11), said electrode (6, 8, 15) being provided on said nitride film (14).

2. A semiconductor device comprising:
(a) a semiconductor substrate (1) having a principal surface;
(b) a plurality of semiconductor elements (22, 23) formed on said principal surface, and each having at least one electrode; and
(c) wiring layers (15) connecting selected ones of the electrodes of said plurality of semiconductor elements, and each including a metal film;
characterized in that said electrode of said semiconductor elements includes a semiconductor layer (11) provided nearer to said principal surface, and a metal nitride film (14) interposed between said semiconductor layer (11) and said wiring layer (15).

3. The device of Claim 2, wherein a metal silicide film (13) is further interposed between said semiconductor layer (11) and said metal nitride film (14).

4. The device of any of Claims 1 to 3, wherein said electrode (6, 8, 15) or wiring layer (15) is made of an Al-alloy film.

5. The device of Claim 1, 3 or 4, wherein said metal silicide film (13) is a platinum silicide or palladium silicide film.

6. The device of any of Claims 1 to 5, wherein said metal nitride film (14) is a titanium nitride film.

7. The device of any of Claims 1 to 6, wherein said semiconductor film (11) is a polycrystalline Si film.

8. The device of Claim 7, wherein said polycrystalline Si film (11) is doped with boron.

9. The device of Claim 7, wherein said polycrystalline Si film (11) contains arsenic or phosphorus in an amount smaller than the limit of solid-solubility of the respective element in Si.

10. The device of any of Claims 7 to 9, wherein the crystal grain size in said polycrystalline Si film (11) is smaller than the thickness of said film.

11. The device of any of Claims 1 to 10, wherein said electrode (15) is an electrode of a transistor, specifically of a bipolar transistor.

12. The device of Claim 11, wherein said electrode (15) is a base lead-out electrode

13. The device of Claim 12, wherein a base region (4) connected to said base lead-out electrode (15) is made of a p-type impurity layer.

FIG. 1

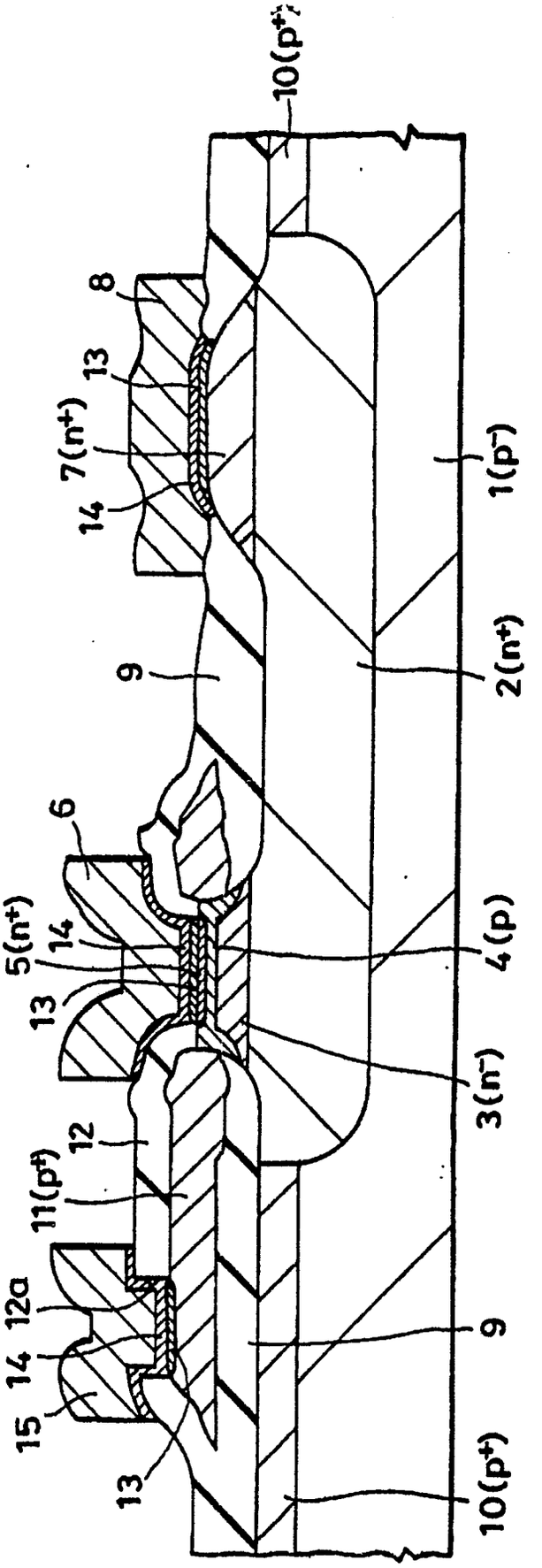
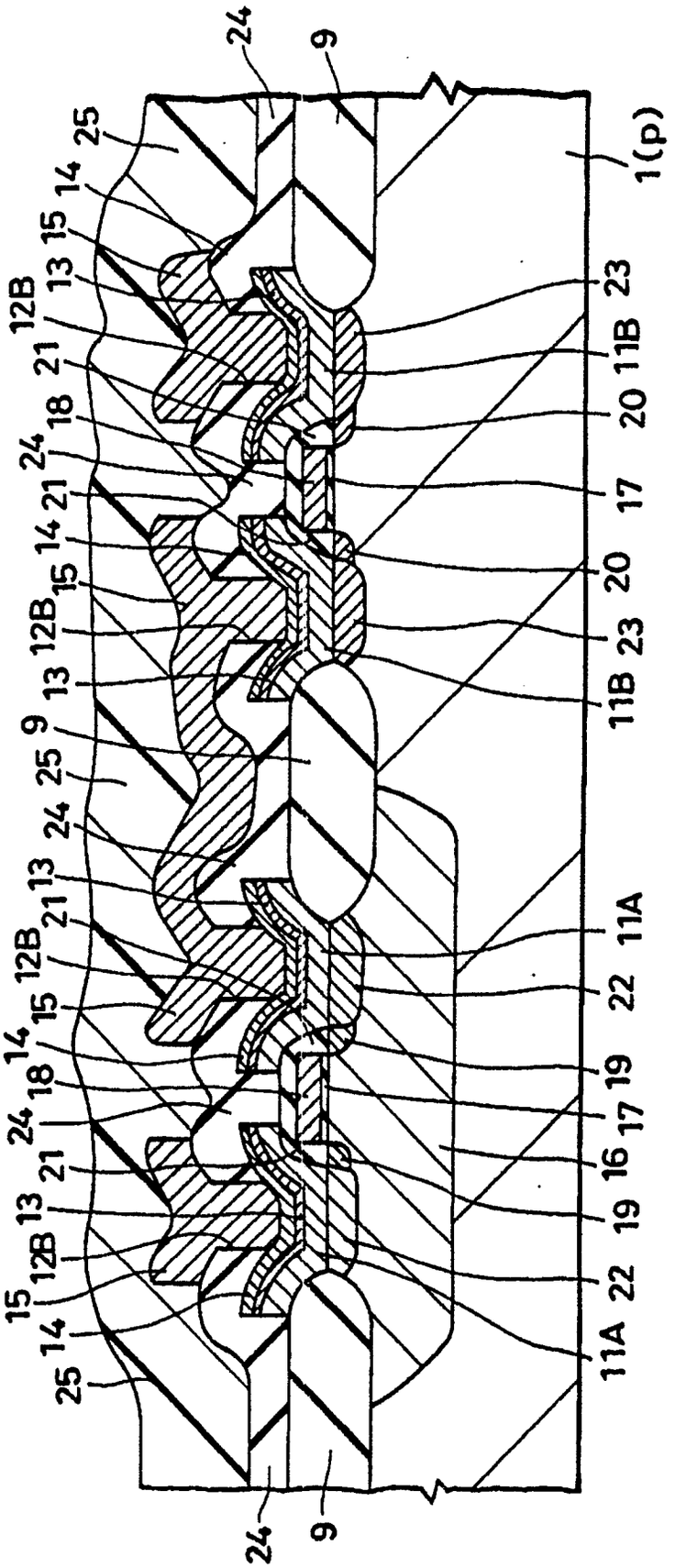


FIG. 2


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EUROPEAN SEARCH REPORT

Application number

EP 87 10 8781

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int. Cl.4)
X	PATENT ABSTRACTS OF JAPAN, vol. 9, no. 31 (E-295)[1754], 9th February 1985; & JP-A-59 175 726 (FUJITSU K.K.) 04-10-1984 * Abstract; figures *	1-7	H 01 L 29/40
Y	IDEM	8-13	
D,Y	IEEE JOURNAL OF SOLID-STATE CIRCUITS, vol. SC-15, no. 4, August 1980, pages 455-459, IEEE, New York, US; H. NAKASHIBA et al.: "An advanced PSA technology for high-speed bipolar LSI" * Pages 455-457, paragraphs II,III; figures 1-3 *	8,9,11-13	
Y	JOURNAL OF THE ELECTROCHEMICAL SOCIETY, vol. 129, no. 8, August 1982, pages 1811-1818, Manchester, New Hampshire, US; S. SOLMI et al.: "Electrical properties of thermally and laser annealed polycrystalline silicon films heavily doped with arsenic and phosphorus" * Page 1813, left-hand column, lines 8-34 *	9	

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TECHNICAL FIELDS SEARCHED (Int. Cl.4)

H 01 L

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	05-11-1987	MORVAN D.L.D.

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
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EUROPEAN SEARCH REPORT

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DOCUMENTS CONSIDERED TO BE RELEVANT

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Y	PATENT ABSTRACTS OF JAPAN, vol. 10, no. 133 (E-404)[2190], 17th May 1986; & JP-A-60 262 452 (NIPPON DENKI K.K.) 25-12-1985 * Abstract; figures *	10	
A	IDEM	1-3,5, 7,9	
X	US-A-4 533 935 (MOCHIZUKI) * Column 4, lines 10-51; column 5, lines 14-19; figures 6a-6e *	1-4,6, 7	
A		5,9,10	

TECHNICAL FIELDS SEARCHED (Int. Cl.4)

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